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(56) Documents Cited

GB 2304760 A WO 98/34006 A1 WO 98/13572 A1

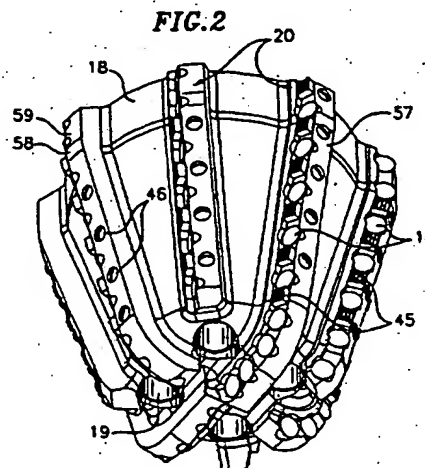
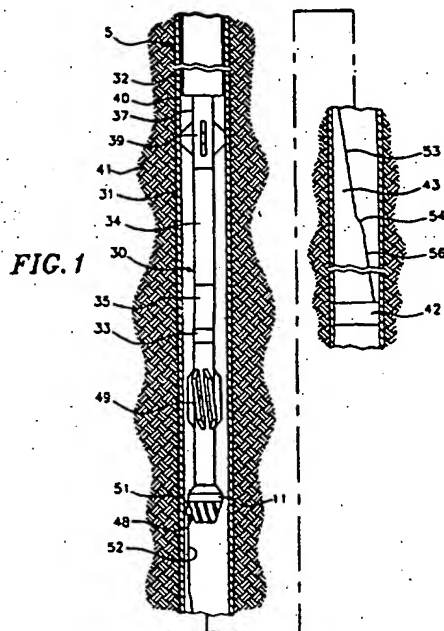
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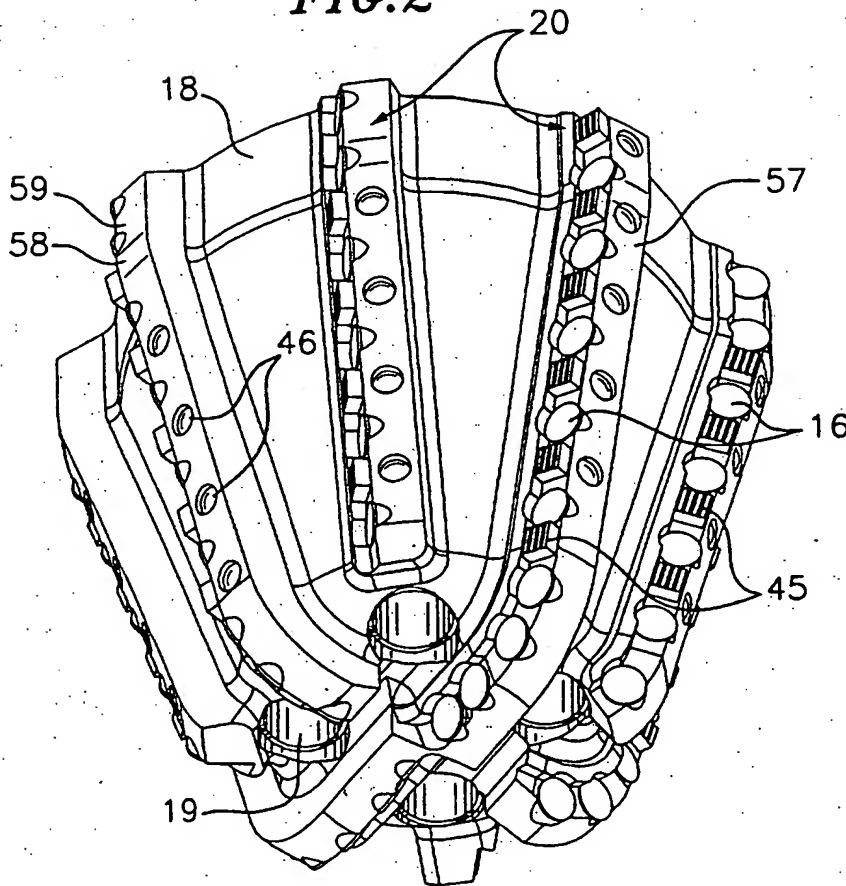
Method for milling casing and drilling formation using a dual function drill bit

(57) A dual function drag bit 11 is used in a method for both milling well casing 40 or liner and subsequently drilling rock formation 41 without the sequential removal of a milling assembly and replacement with a drilling assembly. The method employs a cutting tool that is capable of both milling steel pipe casing in a well bore and subsequently drilling rock formation outside the well bore after passing through the casing. In one embodiment, inserts (16, figure 3) designed for embedding into the surface of a cutting tool 11 comprise at least an outer layer (22, figure 3), such as cemented tungsten carbide, capable of milling steel, and at least a second layer (23, figure 3), such as polycrystalline diamond, capable of drilling formation, the two layers being bonded together and to a carbide substrate (24, figure 3). In another embodiment, inserts 16 with a polycrystalline diamond cutting face for drilling rock formation are in parallel with cemented tungsten carbide cutters 45 for milling steel casing.

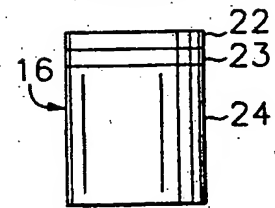


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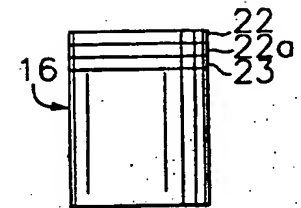
**FIG. 2**



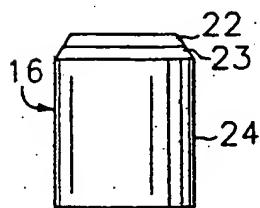
**FIG. 3**



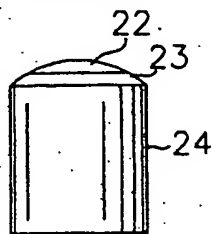
**FIG. 4**



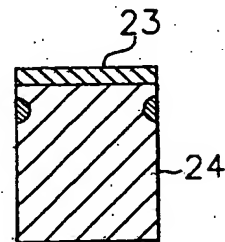
**FIG. 5**



**FIG. 6**



**FIG. 7**



1 disclosed system requires three trips into the well, beginning  
with the creation of an initial window in the borehole casing,  
the extension of the initial window with a particular cutting  
tool, and the elongation and further extension of the window by  
5 employing an assembly with multiple mills.

By integrating a whipstock into the milling operation and  
directionally orienting the milling operation to a more confined  
area of well casing, the number of trips required to effectively  
mill a window in a well casing have been decreased. A whipstock  
10 having an acutely angled ramp is first anchored inside a well and  
properly oriented to direct a drill string in the appropriate  
direction. A second trip is required to actually begin milling  
operations. Newer methods integrate the whipstock with the  
milling assembly to provide a combination whipstock and staged  
15 sidetrack mill. The milling assembly is connected at its leading  
tool to the top portion of the whipstock by a bolt which, upon  
application of sufficient pressure, may be sheared off to free  
the milling assembly. The cutting tool employed to mill through  
the metal casing of the borehole has conventionally incorporated  
20 cutters which comprise at least one material layer, such as  
preformed or crushed tungsten carbide bonded to a carrier,  
designed to only mill pipe casing. The mills used for milling  
casing are not suitable for extensive drilling of rock formation.

Once a sufficient window has been created, the milling  
25 assembly is removed and the drilling assembly is inserted into  
the borehole and directed to the newly formed window to drill  
earthen formation. Directional drilling is achieved by a number  
of conventional methods, such as steerable systems, which, when  
used, control borehole deviation without requiring the drilling  
30 assembly to be withdrawn during operation.

A typical system may use a bottom hole motor with a bent  
housing having one fixed diameter bit stabilizer below the  
housing and one stabilizer above the housing in combination with  
a measurement-while-drilling (MWD) system. Deviation is achieved  
35 by using the motor output shaft to rotate the drill bit while

1 employ a method and incorporate the requisite devices which would  
both mill a window in the original well casing and subsequently  
drill formation through the newly created window in a single  
step.

5 It would be desirable to provide a method and device which  
enables the milling of pipe casing and subsequent drilling of  
formation without requiring multiple trips.

10 The present invention employs a dual-function cutting tool  
that is capable of milling pipe casing and/or liner and  
subsequently drilling formation. An exemplary cutter embedded  
in the cutting tool comprises at least a first material layer,  
such as cemented tungsten carbide, capable of milling pipe casing  
15 and/or liner and at least a second material layer, such as  
polycrystalline diamond, capable of drilling formation, the two  
layers being bonded together and to an insert body. The  
thickness and configurations of the material layers relative to  
each other and to the carrier vary and may include beveled and  
20 twin edge constructions which vary the cutting surface and  
improve the milling and drilling operation.

The cutting tool body is attached to a bottom hole assembly  
that connects to the drill string. The cutting tool may be  
optionally attachable to a whipstock to integrate the packing,  
25 anchoring, and orienting of a whipstock with the insertion of the  
milling and drilling assembly, thereby eliminating the need for  
a separate whipstock placement trip.

The milling and drilling process is conducted by shearing  
off the connection between the whipstock and cutting tool and  
30 directing the dual function milling and drilling assembly down  
the whipstock incline toward the well casing. After a window is  
milled through the casing, directional drilling can then proceed  
by any conventional method. The same cutting tool is used for  
both milling the casing and drilling the rock formation beyond

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1 some level (referred to as a liner hanger point) below the ground  
surface. Typically, either casing or liner is cemented in the  
well bore with a cement grout. Since both are steel pipe and it  
makes no difference for practice of this invention where the pipe  
5 is suspended, the pipe is referred to herein simply as casing.

A preferred embodiment of an apparatus capable of practicing  
the method of the present invention is shown in FIG. 1. A bottom  
hole assembly 30 with a cutting tool 11 which has the capability  
of both milling well pipe casing 40 and drilling earthen  
10 formation 41 includes a series of tools 32-39 between the cutting  
tool 11 and the drill pipe 31, described in greater detail  
hereinafter.

Unlike conventional cutting tools, the cutting tool 11  
employed in the present invention is multi functional in that it  
15 is designed to both mill pipe casing 40 and subsequently drill  
earthen formation 41. While the present invention is not limited  
to any particular design for a multi functional cutting tool  
capable of sequentially milling pipe casing and drilling  
formation, an exemplary embodiment of the cutting tool 11 is  
20 provided in FIG. 2.

In the embodiment shown in FIG. 2, the cutting tool 11, of  
a form commonly referred to as a drag bit, comprises a body 18  
with a threaded shank at the top (hidden in this view) for  
connection to a bottom hole assembly 30. The body 18 may be  
25 formed from steel or a tungsten carbide matrix infiltrated with  
a binder alloy or any other material used in the art. Extending  
outwardly from the base of the cutting tool body 18 are a series  
of arched projections or blades 20 which comprise the cutting  
tool surface and into which are embedded inserts or cutters 16.  
30 Within the cutting tool body 18 are one or more passages ending  
in openings 19 through which drilling fluid may be delivered to  
cool the cutting tool surface and remove accumulated debris.

In the illustrated embodiment, the inserts 16 comprise 13  
mm diameter cylindrical bodies of cemented tungsten carbide with  
35 a layer of polycrystalline diamond (PCD) on an end face. Each

1 As an alternative to providing separate pieces of cemented tungsten carbide on the face of the blades for cutting steel, carbide can be provided on the face of some or all of the PCD inserts. Such a layer of carbide can be used for milling steel casing, and after the bit enters rock formation, the carbide is eroded away leaving the PCD layer exposed for drilling rock formation.

5 As shown in FIG. 3, such an insert 16 comprises material layers 22, 23 which are bonded onto a carrier substrate 24 and then secured into the cutting surface of the cutting tool. As stated previously, the material layers have conventionally been designed to be mono-functional. The present invention uses a first material layer 22 which is capable of milling pipe casing, such as 9 5/8 inch steel casing, bonded to a second material layer 23 which is capable of drilling earthen formation. The type of metal used in the pipe casing and the type of geological formation being drilled determine the materials to constitute the first or outer layer 22 and second material layer 23.

15 Materials such as polycrystalline diamond, polycrystalline cubic boron nitride (PCBN), natural diamond, titanium nitride, tungsten carbide or tungsten carbide cemented with cobalt can be used in either the first layer 22 or second material layer 23, as suitable for the intended functions of milling steel casing or drilling rock formation, respectively. It is within the knowledge of one skilled in the art to choose the proper combination of material layers based upon the type of casing and geological formations being encountered.

25 If milling a 9-5/8 inch steel casing, a preferred embodiment of the present invention employs a first material layer 22 made of cemented tungsten carbide bonded to a second material layer 23 made of polycrystalline diamond. PCBN can be used in the first material layer 22 but, relative to a milling grade of tungsten carbide, it does not mill steel as effectively. Both tungsten carbide and PCBN are preferred materials for the first

1 and is dependent and determined by the expected wear profile.  
One preferred embodiment, shown in FIG. 5, employs a beveled  
structure where the first layer 22 substantially covers the  
second layer 23 and both material layers 22, 23 cover the face  
5 of the insert body. The beveled edge has an angle corresponding  
to the rake angle of the insert mounted in the bit body. This  
may improve the performance of the insert and minimize chipping.  
For directional drilling, a rounded insert profile, shown in FIG.  
6 can be used to attain sufficient side loading. Different  
10 geometries of insert may be used in the gage rows and in inner  
rows on the cutting tool.

The cutting tool 11 is used in conjunction with a bottom  
hole assembly 30 which stabilizes the cutting tool, provides the  
motive force for rotating the cutting tool, and after milling  
15 through casing, directionally controls the movement of the  
cutting tool in rock formation. While components of the bottom  
hole assembly may be varied without exceeding the scope of the  
claimed invention, the bottom hole assembly is described in  
relation to an exemplary embodiment illustrated semi-  
20 schematically in FIG. 1. It will be recognized that the relative  
lengths and diameters of the parts of the bottom hole assembly  
may be rather different from what is illustrated.

The bottom hole assembly 30 comprises drill collars 32, a  
rotatable shaft 33, a bottom-hole motor output shaft (not shown),  
25 bottom-hole motor 34, a bent housing 35, one or more stabilizers  
39 and a connector sub 37. The cutting assembly includes cutting  
tool 11 for milling casing and drilling rock formation as  
provided in practice of this invention, and a second milling tool  
49 above the cutting tool. The cutting tool 11 opens a window  
30 through the casing in a well and the second milling tool enlarges  
and cleans up the shape of the window. A third milling tool may  
also be used if desired. The second and third milling tools are  
conventional watermelon mills or window mills.

The cutting assembly connects to the bottom hole assembly  
35 30 by connecting to the rotatable shaft 33 which, in turn, is

1        The bottom hole assembly can be connected to the whipstock  
to both facilitate positioning and eliminate the requirement of  
separate trips for positioning the whipstock and initiating  
milling and drilling operations. The cutting tool 11 may be  
5       connected to the top portion of the whipstock by a bolt 48 which,  
upon application of sufficient pressure, is sheared off, thereby  
releasing the bottom hole assembly from its fixed position  
relative to the whipstock and permitting it to proceed down a  
path toward the pipe casing defined by the inclination of the  
10      face of the whipstock. The connection between the bit and the  
whipstock may be hollow and/or connected via a port through the  
body of the bit so that upon shearing off of the connection, the  
port is opened and serves as a fluid port during the milling and  
drilling operation.

15       The drag bit for milling casing and drilling adjacent rock  
formation after a window is cut through the casing, is preferably  
used with a whipstock having complementary surfaces, as described  
in U.S. Patent Application Serial No. 08/642,829, assigned to the  
same assignee as this application. The subject matter of the  
20      pending application is hereby incorporated by reference.

In a typical embodiment, the whipstock has a ramp surface  
with several different angles relative to the axis of the  
borehole in which it is placed. At the upper end of the  
whipstock there is a short surface 51 having an angle of about  
25      15° which is useful for starting the cutting of a window. Just  
below the starting ramp 51, there is an elongated surface 52,  
which is parallel to the axis of the hole. The length of the  
parallel surface is about the same as the distance between the  
first cutting tool 11 and the second milling tool 49. Next,  
30      going down the borehole, there is a ramp surface 52 on the  
whipstock with an angle of about 3° from the borehole axis. The  
3° surface continues until it reaches approximately the  
centerline of the borehole. At that elevation there is a short  
15° "kickoff" surface 54. Below the kickoff surface the face of  
35      the whipstock reverts to a 3° angle.



1 3° portion of the cutting tool engages the 3° ramp surface 53 on  
the whipstock, and is further forced laterally into the casing  
and surrounding cement; gradually enlarging both the length and  
width of the window through the casing. The watermelon mill  
5 follows, cleaning up the window made by the cutting tool.

As the center of the cutting tool approaches a point where  
it should be milling casing, the 15° portion of the cutting tool  
engages the kickoff surface 54. This tends to force the cutting  
tool laterally through the casing and surrounding cement at a  
10 relatively rapid rate through the portion of the milling  
operation where the center of the cutting tool is cutting the  
steel of the casing. This is a part of the milling operation  
where the rate of penetration is relatively lower and is desired  
to proceed through this part rapidly.

15 After the center of the dual function cutting tool has  
passed through the casing, the cutting tool engages the final 3°  
ramp 56 on the whipstock and proceeds to enlarge the window  
through the casing and extend further into the rock formation.  
Meanwhile, the second milling tool 49 continues to enlarge and  
20 clean up the window through the casing.

Typically, in the past, the sidetracking operation has  
continued after the initial milling tool has passed through the  
casing to produce a short rat hole in the formation adjacent to  
the original borehole, which has sufficient length to accommodate  
25 at least the second (and third if used) milling tools, and  
usually a small additional portion of the bottom hole assembly.  
The prudent driller typically makes the rat hole deep enough to  
assure that the subsequent drill bit will pass cleanly through  
the window. A typical rat hole is four or five meters deep and  
30 is not drilled deep enough to accept the entire bottom hole  
assembly.

The bottom hole assembly embodiment of FIG. 1 permits the  
exertion of directional control over the milling and drilling  
process. As discussed in RE 33,751, the offset of the cutting  
35 tool from center, created by the bend angle of the bent housing

1 Further cutting of the rock formation outside the casing is  
usually undesirable since the conventional casing mill is  
designed specifically for cutting casing and is not particularly  
well suited for drilling formation. Certainly the milling tool  
5 would not be run into the formation more than fifteen meters  
beyond the bottom of the window, far beyond the usual depth of  
the rat hole. The casing mill wears rapidly in the rock  
formation and is not suitable for drilling to the next liner  
hanger point or true bottom of the well. At the point where a  
10 rat hole has been formed, a conventional casing mill would be  
withdrawn from the borehole and a conventional drill bit run in  
for drilling rock formation outside the casing. The conventional  
drill bit is not particularly well suited for milling casing and  
would, typically, have unacceptable wear when so used.

15 In practice of this invention, however, the same drag bit  
is used for milling through the casing and for drilling rock  
formation to the next liner hanger point, for example. This is  
typically more than fifteen meters beyond the sidetracked well  
bore, much further than a traditional rat hole. As the dual-  
20 function bit drills further into the formation the downhole motor  
and bent housing assembly are used for steering to provide  
directional control of the borehole being drilled. Alterna-  
tively, steering may be provided by way of a steerable bottom  
hole assembly on a rotating drill string.

25 In an embodiment with inserts as described and illustrated  
in Fig. 3 are employed, when the inserts 16 have had the outer  
material layer designed to mill the pipe casing worn away, the  
second material layer 23 designed to drill formation is exposed.  
The drilling of rock formation continues due to the rotary  
30 application of the combined milling and drilling tool to  
formation for a desired distance beyond the length of a  
conventional rat hole. The drilling of formation can continue  
without requiring the removal and/or replacement of the drilling  
assembly until the next liner hanger point is reached by the

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1 wear away in the rock formation and the PCD inserts take over the  
drilling operation.

5 In an exemplary sidetracking operation, a window may be cut  
in a 9-5/8 inch casing and about 100 meters of hole drilled with  
an 8-1/2 inch drilling bit. A 7-1/2 inch liner is then cemented  
in the sidetracked hole, and a 4-1/2 inch bit used to drill  
further into the formation. Traditionally, two bits are used for  
milling the casing and drilling the 100 meter extension. With  
this invention, a single dual function drag type bit with PCD  
10 inserts may be used for both milling a window through the casing  
and extending the hole 100 meters or more through the formation  
for placement of a liner.

In another embodiment, a layer of PCD may be formed on a  
carbide body. This is covered with a layer of titanium nitride  
15 or titanium carbonitride which is used as the material for  
milling the steel casing.

Still another embodiment of insert, as illustrated in FIG.  
7, has what amounts to two cutting edges. A carbide body 24 has  
a layer 23 of PCD on an end face. A layer of carbide may be  
20 formed or brazed over the PCD if desired, or the diamond layer  
may be used for milling the steel casing. In this embodiment  
there is also a ring or band of PCD formed in a circumferential  
groove around the cemented tungsten carbide body. As this  
embodiment of insert is used, the layer of PCD on the front face  
25 may wear and the additional band of PCD then serves as a second  
cutting edge. If desired, the edges of the insert may be beveled  
at the rake angle so that the second cutting edge is exposed at  
the beginning of drilling.

The inserts described and illustrated herein have each  
30 featured a cylindrical cemented tungsten carbide body with  
layers of material for milling casing and drilling rock formation  
on one end face. It will be apparent to those familiar with drag  
bits that other types of inserts may be employed. For example,  
one popular type of PCD insert has a disk-like carbide substrate  
35 with a layer of PCD formed on one face. This disk of carbide is

1     CLAIMS

1. A method of drilling a portion of a well comprising the steps of:

- 5     introducing a dual function tool into a well bore;  
      milling a window in well casing in the well bore with the dual function tool, including drilling a rat hole in formation adjacent to the well bore; and  
      continuing to drill formation beyond the end of the rat hole  
10    with the same dual function tool.

2. A method of drilling a portion of a well comprising the steps of:

- introducing a dual function tool into a well bore;  
15    milling a window in well casing in the well bore with the dual function tool; and  
      continuing to drill formation adjacent to the well bore with the same dual function tool until at least an entire bottom hole assembly connected to the dual function tool has passed through  
20    the window in the well casing.

3. A method of drilling a portion of a well comprising the steps of:

- placing a sidetracking whipstock in a well bore;  
25    introducing a dual function tool into the well bore;  
      milling a window in well casing adjacent to the whipstock with the dual function tool; and  
      continuing to drill formation adjacent to the well bore with the same dual function tool beyond a location where the whipstock  
30    has an influence on the direction of drilling by the dual function tool.

1 continuing to drill formation adjacent to the well bore with  
the same dual function tool to the true end of the well.

8. A dual function bit for milling casing in a well bore  
5 and for drilling rock formation outside the well bore comprising:  
a drag bit body; and  
a plurality of inserts in the drag bit body, each of the  
inserts comprising:

an insert body,

10 a layer of polycrystalline diamond material on a  
cutting face of the insert body, and

a layer of softer material over the layer of  
polycrystalline diamond, the softer material layer having  
a sufficient hardness and thickness for milling through  
15 steel casing in a well bore.

9. A dual function bit according to claim 8 wherein the  
layer of softer material is selected from the group consisting  
of polycrystalline cubic boron nitride, titanium nitride,  
20 titanium carbonitride, tungsten carbide or cemented tungsten  
carbide.

10. A dual function bit according to claim 8 wherein the  
layer of softer material comprises cemented tungsten carbide.

25 11. A dual function bit for milling casing in a well bore  
and for drilling rock formation outside the well bore comprising:

a drag bit body; and

a plurality of inserts in the drag bit body, each of the  
30 inserts comprising an insert body having a layer of  
polycrystalline diamond material on a cutting face of the insert  
body for drilling rock formation; and

a plurality of cemented tungsten carbide cutters mounted on  
the body in parallel with the inserts for milling steel casing.

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Application No: GB 9903332.6  
Claims searched: 1

Examiner: Dr. Robert Fender  
Date of search: 10 May 1999

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): E1F

Int Cl (Ed.6): E21B

Other: Online: WPI, EPODOC

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2304760 A (TIW CORPORATION)	1
X, E	WO 98/13572 A1 (BAKER HUGHES INCORPORATED)	1
A	WO 98/34006 A1 (WEATHERFORD/LAMB)	-

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
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A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.